Reed Canarygrass Annotated Bibliography

Boundary Hydroelectric Project (P-2144)

Terrestrial Resources Management Plan

Prepared by

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A significant portion of floodplain at the Boundary Wildlife Preserve (BWP), which is one of the Project Habitat Lands within the Boundary Hydroelectric Project (Boundary), has varying amounts of reed canarygrass (RCG). Though there is some evidence that a native species of RCG occurred in Washington prior to European settlement, early collections suggest this species was not widespread. There have been multiple, uncontrolled introductions of European genotypes and cultivars since the late 1800's. Dense monotypic stands of RCG that displace native wetland plant associations are thought to be formed by non-native, European genotypes or one or more hybrids that have broader ecological amplitude than the native form. The Terrestrial Resources Management Plan (TRMP) for Boundary includes an objective to evaluate management options for increasing native wetland and riparian plant species such as sedges, rushes, willows, and black cottonwood at the BWP. This literature search was conducted on RCG to gather information to assist Seattle City Light and the Terrestrial Resources Working Group develop a pilot study for controlling RCG and enhancing native wetland and riparian plant associations on the BWP by replacing RCG with native trees, shrubs, and graminoids.

This document consists of two parts. The first part includes an annotated bibliography on literature reviewed. The list of literature reviewed is not exhaustive by any means as there are thousands of publications on RCG and invasive species and ecology of black cottonwood trees and native shrubs that provide habitat to wildlife. The bibliography contains a good mixture of the most relevant articles published in peer-reviewed scientific journals, academic publications (M.S. theses and Ph.D. dissertations), natural resource management agency documents, and gray literature or white papers that document the biology and ecology of RCG and effective control methods or management practices. Because of the history of RCG, there is a tremendous amount of genetic variation and review of literature focused more on regional publications. Scott Luchessa, Senior Environmental Analyst and certified ecologist used his more than 30 years of experience, including more than 15 years of experience designing and implementing terrestrial and wetland habitat restoration plans involving RCG management. Titles of publications reviewed are shown in alphabetical order in bold type followed by key words and a summary of the document. The summary of some documents also includes comments about applicability to or implications for planning and design of future Boundary habitat mitigation. Part two of the document contains a bibliography of literature not reviewed but that may be of interest to others. Documents included in this part of the document includes older literature that may be referenced in literature reviewed or is more purely academic in nature and was judged not to be germane to future mitigation planning. Titles in part two also are in alphabetical order but in plain type.

LITERATURE REVIEWED

Anonymous. No Date. West Eugene wetlands reed canarygrass distribution and management plan. West Eugene Wetlands, Eugene, OR.

Key Words: West Eugene Wetlands, Oregon, biology, mowing, burning, herbicide, hydrologic alteration, tilling, hand pulling.

The West Eugene Wetlands is a 3600 acre wetland mitigation bank complex in Eugene, Oregon. It includes some relatively high quality wet prairie remnants. In spring 2000, the distribution of RCG was mapped using a combination of aerial photographs and field verification. RCG covered approximately 100 acres. A management plan was developed for 17 areas of varying size (<1 acre to ~13 acres) and density (0.01 to 100% cover) representing the greatest threat to high quality wetlands within the mitigation bank. Management was prioritized based upon the presence of rare plant and animal species, threat of RCG populations to these, and focusing limited resources on RCG populations where the goal of eradication is most achievable. Brief discussion of a variety of control methods, including herbicide, burning/flaming, cutting/mowing, tilling/disking, solarization, alteration of hydrology, and hand pulling. Good explanation of the strategy for each control method and when it is most effective. Nice tabular summary of advantages and disadvantages of each method. Because of prohibitions on burning and herbicide use and limited resources, annual or biannual mowing was recommended to stress plants and reduce the rate of spread. First mowing early June followed by second mowing in late September/early October.

Apfelbaum, S.I. and C.E. Sams. 1987. Ecology and control of reed canary grass (*Phalaris arundinacea* L.). Natural Areas Journal 7(2):69-74

Key Words: Biology, life history, seeds, tiller depth, control,

This is one of the earliest papers describing the invasive attributes of RCG and summarizing the findings of early control efforts much of which was focused in the Midwest. There are brief discussions of chemical control with herbicides, mechanical control, and burning. More recent publications reviewed herein have more current and applicable information based on control efforts in the PNW. Citing Comes et al. 1981, the authors report 97% of seed germinated immediately after harvest in a greenhouse experiment. “The plant is capable of producing dense rhizome growth in suitable habitat within one growing season.” At least 88% of emergent shoots on established plants were found to be from rhizomes or tiller buds in top 5 cm of soil. Both seed and rhizomes readily establish new plants and are easily dispersed along ditches and waterways. In the PNW, most shoots originate on shoots from rhizomes or tiller buds within 15 cm of the ground surface (personal observation, S. Luchessa). Authors cite Comes et al 1981, which likely built on Comes' 1971 PhD. dissertation at Oregon State University, state "few shoots arose from buds deeper than 20 cm and no tillering occurred below this depth.

Antieau, C.J. 2006. Biology and management of reed canarygrass, and implications for ecological restoration. Washington State Department of Transportation, Seattle, WA.

Key Words: White paper, Pacific Northwest RCG Work Group, mowing, grazing, tilling, disking, burning, flaming, mulching, flooding, succession, neo-climax community

This is the most current and detailed white paper summarizing the knowledge base of the Pacific Northwest Reed Canarygrass Working Group, which was managed for a number of years by Clay Antieau. This is an excellent summary of RCG biology and life history characteristics and various management practices. Much of this information is based on regional genotypes of RCG and regional applications of control methods. *Note that the footer indicates 2006 though a copyright note on the first page indicates 1998.* Discussion of management practices or control methods are well supported with literature citations. An integrated management strategy is recommended. The author suggests that in the absence of intervention, infestations prevent succession to climax plant communities naturally found in the region thus forming a neo-climax community. This assertion appears to be supported by the presence of monocultures of RCG in some areas at the BWP and many other areas in the northwest for decades.

Antieau, C.J. 2001. Biology, ecology, and management of invasive plants. In: Haase, D.L. and R. Rose (eds). Native plant propagation and restoration techniques. Proceedings of a conference December 12-13, 2001 sponsored by the Nursery Technology Cooperative and Western Forestry and Conservation Association.

Key Words: White paper, invasive species, noxious weed, edge effect, mowing, grazing, tilling, disking, burning, flaming, mulching, flooding

This is a somewhat more broadly focused and general white paper on invasive plant species in the Pacific Northwest and habitat restoration methods. It contains similar information but less detail than the more current 2006 white paper. This version has a very general and cursory discussion of RCG biology. There is a fair discussion of weed management, impacts on ecosystem integrity, micro-nutrient management, and edge effects.

Antieau, C.J. 2000. Emerging themes in RCG management. AWRA International Conference on Riparian Ecology and Management in Multi-Land Use Watersheds Conference, Portland, Oregon; 28-30 August 2000

Key Words: Pacific Northwest, biology, life history, succession, control, management practices, mowing, grazing, disking, burning, excavation, mulching, flooding, chemical (herbicide), shading

This is more or less an earlier rendition of his 2006 white paper. It contains a good overview of RCG biology: sexual and asexual reproduction, and phenology. Good overview of management techniques in

PNW: mowing, grazing, disking, burning, excavation, mulching, flooding, chemical (herbicide), shading (succession), and recommended, integrated strategies

Antieau, C.J. (ed). 2000. Final Proceedings of the Reed Canarygrass Working Group Conference, March 15, 2000 at the USDA Forest Service, Service Center, Olympia, WA.

Key Words: Pacific Northwest, succession, control, management practices, IPM, mowing, grazing, disking, burning, excavation, mulching, flooding, chemical (herbicide), shading, restoration

The final proceedings contain abstracts of presentations made at the conference. Many of these are wetland restoration projects by resource management agencies and consultants and present lessons learned managing RCG at restoration sites. All of these are located within the Pacific Northwest. Various control methods or management practices were used at the various projects, including flooding, mowing, excavating, shading, herbicide, tilling, or a combination of these practices. Summaries of those abstracts that are potentially applicable to management of RCG at the Boundary project are cited individually within this annotated bibliography.

City of Eugene. 2013. Integrated pest management plan (IPM) policy and operations manual. Public Works Department, Parks and Open Space Division, Eugene, OR.

Key Words: herbicide, best management practice, BMP, hand removal, solarization, glyphosate, mowing

The IPM contains appendices that provide BMPs for specific invasive species, including RCG, for different management areas within the City of Eugene. Recommended BMPs include mowing in combination with foliar spraying (1.5% glyphosate) in fall and shading/solarization for patches < 5,000 sq. ft. Hand pulling/digging may be used for removing small, isolated patches.

Darris, D. 2000. Native grasses, forbs, and sedges for reed canarygrass competition studies: seed collection and increase phase. In: Antieau, C.J. (ed). 2000. Reed Canarygrass Working Group Conference, Olympia, WA.

Key Words: Pacific Northwest, seed mix, competition, Puget Trough, Plant Materials Center

The Corvallis Plant Materials Center of the Natural Resources Conservation Service (NRCS) identified a number of potential native grasses, forbs, and sedges that may be able to successfully compete with RCG. Identified species includes, rice cutgrass (*Leersia oryzoides*), big-leaf lupine (*Lupinus polyphyllus*), *lmpatiens* spp., bluejoint reedgrass (*Calamagrostis canadensis*), meadow barley (*Hordeum brachyantherum*), slough sedge (*Carex obnupta*), and other sedges (*Carex* spp.). Seeds from western Washington and western Oregon ecotypes of these species are being collected in the wild and increased for seed at the materials center. Once sufficient seed has been grown, greenhouse, plot, and in-situ field studies will be undertaken to see if these species can compete with RCG under a variety of soil and hydrologic conditions. City Light has reached out to see if these studies were ever completed and contemplating possibly using a custom seed mix in the pilot mitigation project at Boundary, depending on the findings or the NRCS research.

Dukes, T. 2000. Reed canarygrass control in the Olympic region, Washington State Department of Transportation. In: Antieau, C.J. (ed). 2000. Reed Canarygrass Working Group Conference, Olympia, WA.

Key Words: Pacific Northwest, Hylebos Waterway, Tacoma, Andrews Creek, Jefferson County, herbicide, mechanical

Chemical (herbicide) and mechanical control methods were used at two wetland restoration sites: Hylebos Waterway in Tacoma and Andrews Creek near Quilcene in Jefferson County, Washington. Herbicide was applied with a backpack sprayer and wicking apparatus. Treatments were effective in reducing but not eradicating RCG. Black landscape fabric also was used to try and shade RCG, which was reportedly ineffective. It is unclear what mechanical methods were used but WSDOT often uses a combination of mowing to reduce carbohydrate reserves in rhizomes and reduce the amount of herbicide needed to cover and treat resprouting RCG.

Fierke, M.K. and J.B. Kauffman. 2005. Structural dynamics of riparian forests along a black cottonwood successional gradient. Forest Ecology and Management 215:149–162

Key Words: Black cottonwood, Populus balsamifera, succession, tree density, Willamette River, Oregon

Nice summary in the introduction of human alterations to ecosystem processes which have reduced the natural regeneration of black cottonwood forests. "A significant reduction in peak flow events in the last century may help explain the lack of riparian forest regeneration we noted, as germination and establishment of young cottonwoods was limited to low areas subject to annual flood inundation and scouring." Objectives of this study were to quantify and describe successional change, stand development and biomass accumulation in various black cottonwood riparian forest stands ranging from recently established seedlings to late-successional stands using a chronosequence approach. Five habitat variables were delineated in the 28 sampled stands: geomorphic position, riverine position, and meander position were based on fluvial processes outlined in Leopold et al. 1964. More details on different geomorphic, riverine, and meander positions are provided in the methods. Longitudinal position and stand area were the other recorded habitat variables. Quantitative structural characteristics of stands were recorded (species, dbh, height, age, snags, and volume of downed wood) in different sizes of nested plots. Biomass equations were developed for black cottonwoods >30 cm dbh using published bole volume equations, wood density, and calculated component biomass relationships. For smaller 0-5 cm dbh trees, allometric dbh-biomass relationships were determined using standard regression techniques. Authors show statistically significant relationships between lack of natural regeneration, cottonwood stand structure, tree size and abundance and reed canarygrass cover. Good summary of the characteristics of different ages of black cottonwood forest stands. Suggest that lack of regeneration or re-initiation of black cottonwood stands also may be the result of dense RCG, which is known to inhibit successful seed germination. This study provides a good explanation for the lack of natural regeneration of black cottonwood forest associations at Boundary. Management of peak flows by upstream dams has likely removed periodic disturbance events that resulted in scouring and conditions to cottonwood germination and establishment

Fitzpatrick, G.S. 2004. Techniques for restoring native plant communities in upland and wetland prairies in the Midwest and West Coast regions of North America. The Nature Conservancy, Eugene, OR.

Key Words: Prairie restoration, cultivation, herbicide, glyphosate, post-emergent herbicide, flaming, infrared burning, solarization, carbon addition, mycorrhizal inoculation, mowing

Good discussion of the various short- and long-term RCG control methods. Similar to Tu 2004 but focused here on prairie restoration. There is no one control method or combination of control methods that works for all restoration sites. Each site is somewhat different (i.e., past disturbance, plant composition, soils, topography, hydrology, and climate). Literature review on the effectiveness of prairie restoration in meeting five objectives:
1) Control of non-native vegetation; 2) Control non-native seed banks; 3) Improve the competitive environment for native plants; 4) Successful planting of native species; and 5) Successful short and long-term management. Cultivation (tilling, disking, plowing, and harrowing) are identified as measures to temporarily suppress non-natives and preparation for sowing native prairie seeds. Although a single herbicide treatment may effectively control weeds for a season, multiple treatments are generally more effective. A study in Washington (Ewing 2002), found glyphosate reduced biomass of velvet grass (*Holcus lanatus*), tall fescue (*Festuca arundinacea*), Kentucky bluegrass (*Poa pratensis*), and redtop (*Agrostis alba*) in the short term to about 40 g/m^2 but by the third growing season after treatment weed biomass increased to about 480 g/m^2. "Although herbicides may provide only short-term control, it may be sufficient to allow native plants to emerge and become established." Herbicide in conjunction with other treatments (e.g., burning) may provide better control of weeds through reduction in the soil seed bank. Sometimes using a nonspecific herbicide such as glyphosate, along with a selective, post-emergent herbicide like Imazapic (which does not affect certain broadleaf plants and many grasses) can be more effective at reducing weed cover and increasing native species (Beran et al. 1999, Cox 2003). A disadvantage of using herbicides is that soil microflora and fauna may be adversely affected. Some organic herbicides, such as acetic acid and corn gluten have been reported as potential alternatives though control methods are generally lower and no data are cited for RCG. Some disadvantages of organic or natural herbicides include high costs, lack of availability in large quantities and uncertain effectiveness or insufficient information on application rates. Carbon addition of 1,000 to 1, 500 g m^{-2} on upland prairie has been found to reduce weed biomass and promote native prairie plant growth. Additions of 2,000 g m^{-2} (Davis 2001) of sawdust and sugar added on an Oregon wetland prairie significantly reduced non-native grasses and forbs and available nitrogen and increased biomass of two out of three native grasses that were sown. This may not be practicable for sites with constrained or poor access or cost-effective, depending on costs of incorporating such C additions into the soil. Good discussion of mycorrhizal fungi relationships in disturbed versus undisturbed sites. Spot spraying following seeding found helpful.

Golner, G.P. 2000. Lower Columbia River wetlands restoration and evaluation. In: Antieau, C.J. (ed). 2000. Final Proceedings of the Reed Canarygrass Working Group Conference, Olympia, WA.

Key words: Pacific Northwest, wetland restoration, Columbia River, Oregon, flooding, wildlife management areas, disking, succession

Ducks unlimited developed a wetland and riparian restoration and evaluation program for 40 restoration sites within 5 wildlife management areas on or near the Lower Columbia River in northern Oregon and southern Washington. A combination of disking and flooding was used to manage RCG and enhance wildlife habitat, particularly for birds at the Sandy River Delta and Sauvie Island Wildlife Area in Oregon and the Vancouver Lowlands, Shillapoo Wildlife Area, and Ridgefield National Wildlife Refuge in Washington. The depth and duration of flooding was manipulated with the goal of creating more diverse wetland complexes by reducing the cover of RCG and stimulating native plants. Each wetland restoration site will be surveyed (wildlife use, vegetation diversity, and hydrologic response) for a minimum of three years to document changes in vegetation and wildlife use. City Light has reached out to Ducks Unlimited in Vancouver to find out more details on the control strategies and success of these projects.

Hartema, L., P. Adler, C. Toal, and J.J. Latterell. 2014. Rapid update for the Zech property willow study. King County Water and Land Resources Division, Seattle, WA.

Key Words: Sitka willow, Enumclaw, live stakes, whip, percent cover, percent survival, cost, Washington

Three different sizes of Sitka willow (*Salix sitchensis*) were planted in a randomized block design of 30, 15 ft x 30 ft plots in seasonally flooded RCG that had been unmanaged for at least 5 years. Year 2 post-planting data are summarized here. The site is located in Enumclaw, Washington. Three willow treatments (10 plots ea) of:

1) ¼ to ½ inch diameter x 6 ft tall, nursery stock whips;
2) ¾ to 1-inch diameter x 6-ft tall, nursery stock whips;
3) ¾ to 1.5-inch diameter x 6-ft tall, whips from a donor site.

Willows were installed in 2013. Monitoring was conducted to quantify cover and survival over a period of two years (2014 and 2015). After two growing seasons, the larger stock sizes exhibited significantly ($p<0.05$) higher survival and cover. Avg survival was 65% < 83% < 99% for the three respective stock classes from smallest to largest. Statistically significant differences in percent cover were likewise observed between the different size classes. Avg cover was ~16 < ~34% < ~56% for the three respective size classes from smallest to largest. Larger nursery stock whips was the most cost-effective treatment but the largest cuttings collected onsite had the highest survival and cover after two growing seasons. Though it may be a bit more expensive, collecting cuttings from established populations of native shrubs, including red-osier dogwood, willow, and black cottonwood at Boundary for the pilot project would likely be most effective as these species would be adapted to existing edaphic and hydrologic conditions.

Hovick, S.M. and J.A. Reinartz. 2007. Restoring forest in wetlands dominated by reed canarygrass: the effects of pre-planting treatments on early survival of planted stock. Wetlands 27:24–39

Key words: Glyphosate, bareroot, shading, plowing, burning, mowing, combination, herbicide, forested wetland restoration

This is a two year, in-situ study in the upper Midwest (Wisconsin) examining the combined effects of various control methods and shading by native woody plants on dense stands of RCG. Near monocultures of RCG were subjected to four pre-planting treatments: fall herbicide; summer mowing followed by fall herbicide; fall herbicide followed by spring plowing; and fall herbicide followed by spring burning. One to three-year-old trees and shrubs (bareroot) of 23 native species were planted into the four treatments and control plots at three sites over two seasons. Fall herbicide (0.7% glyphosate) application following the first hard frost combined with spring plowing contributed to the highest survival and initial growth rates of transplanted woody species. All treatments provided reasonably high survival of woody plants (avg all spp = 58.7%; top 10 spp avg = 81%. Survival of willow live stakes (8-30 mm diameter and 40-60 cm length) was relatively low (average = ± 26%). Survival of collected species of willow was higher than purchased live stakes.

Iannone, B.V. III and S.M. Galatowisch. 2008. Altering light and soil N to limit *Phalaris arundinacea* reinvasion in sedge meadow restorations. Restoration Ecology 16:689–701

Key Words: Competition, restoration, carbon amendment, C:N, cover crop, RCG establishment
Authors developed cover crop seed mixes and high C:N amendment treatments in a field study to examine whether reducing nutrient availability (especially nitrogen) and sowing non-persistent cover crops may limit RCG invasions in restored sedge meadows in Minnesota. Treatments included high-diversity cover crop, low-diversity cover crop, no cover crop (control) and with or without sawdust amendments (high C:N amendment). Sawdust amendments involved removing the top 7 cm of the existing clay loam soil, adding 8.40 ± 0.13 kg dry weight m^{-2} cedar sawdust, equivalent to a 2:1 soil to sawdust ratio by volume, and tilling the top 20 cm. Hydrology was controlled. Aboveground biomass was measured after two growing seasons and light and soil nitrogen were measured throughout the study. Cover crops exerted a significant competitive effect on the target sedge community and RCG by reducing both light and soil nitrogen. High C:N amendment also had a significant effect on RCG. Authors concluded that rapidly establishing a perennial plant community may be more important than reducing initial resource availability when trying to control invasions of resource-rich restoration sites. Thomsen et al. (2012) cite this study in support of their statement that rapid establishment of a canopy of woody species in forested wetland restoration is critical to limiting light and controlling germination of RCG from the soil seedbank and regrowth. This appears to be directly applicable to establishment of willow and black cottonwood patches for improving wildlife habitat at the Boundary Hydro Project (i.e., rapid establishment of woody scrub-shrub and forest canopy).

Jenkins N.J., J.A. Yeakley, and E.M. Stewart. 2008. First-year responses to managed flooding of Lower Columbia River bottomland vegetation dominated by *Phalaris arundinacea*. Wetlands 28:1018–1027

Key Words: Oregon, restoration, Columbia River, flooding, aboveground cover, biomass

Study in the Smith and Bybee Wetlands Natural Area in Portland, Oregon examining the effects of controlled flooding and shade on RCG. Good discussion on variable effects of flooding on biomass in the introduction. Duration, depth, and timing of flooding influence effects. Reduction in RCG cover (aboveground biomass) varied by depth and duration of flooding and was more effective in combination with shade from regenerating willow forest. Flood depths ranged from 0.7 to 1.15m and varying durations ranging from 89 to 177 days. Most areas inundated from January through June or July. Suggest the effective depth of winter-spring flooding is ≥ 0.85 m. Timing of these depths and durations also varied. Greatest reduction was achieved in areas inundated to ≥ 0.85 m in spring where willows provided shade. Spring flooding at depths between 0.5 and 0.85 m increased aboveground cover of RCG. Though flooding has been shown to be effective in controlling RCG, this method may not be possible to use at Boundary.

Kettenring, K.M. and C. Reinhardt Adams. 2011. Lessons learned from invasive plant control experiments: a systematic review and meta-analysis. J. Applied Ecology 48:970-979

Key Words: Control, invasive, cost, effective, restoration, herbicide, cutting, burning, removal, revegetation, review

Good critical review of limitations of 355 field studies (greenhouse, lab, and agricultural experiments were excluded) published between 1960 and 2009 examining control of invasive species. Seventy-eight percent (~277) of the studies assessed the effects of control methods. The remaining 22% (78 studies), assessed before-and after-comparisons from restoration projects or adaptive management projects. RCG was among the most commonly studied (15 of 355). Common short comings include short duration of research (often one growing season), small-scale treatments (81% < 30 m^2), lack of cost estimates for control methods, and failure to synthesize results in a meaningful context for resource managers (e.g., large-scale restoration with often limited resources). Authors asked two questions: 1) What control efforts, tools, or approaches for invasive plant control have been most effective across invaded ecosystems? 2) How are invasive plant control methods best evaluated for relevancy to restoration practice and translated into successful restoration application? Examined quantitative invasive plant control studies evaluating the response of both plants targeted for control and native plants. Five most frequently used control methods (herbicide, cutting, burning, removal, and native revegetation). Biological control was excluded because of a systematic review recently conducted by others. Herbicide was the most effective control method reducing cover, density and biomass of target species but did not result in a substantial increase in native species. Many studies (60%) report need for repeat treatments for long-term control of invasive species, particularly for herbicide applications and hand-pulling/removal. The authors report several important general conclusions: Invasive plant control can result in re-invasion by the target plant or colonization by new invasive through resource release and reduction in competition, particularly in the absence of successful restoration of native plants; control methods can adversely affect native plants; long-term management often requires repeat application of control methods, the cost considerations of which are rarely evaluated or identified. Control results and restoration of native plant communities are often highly variable. Few studies produced gains in native plant cover, density, or biomass, likely a reflection of short duration of most studies (≤ 2 years). It is important to consider whether restoration of native plant communities may be propagule limited.

Active native revegetation may be necessary. Reintroducing propagules of native plants can accelerate the development of native plant communities and reduce reinvasion of invasive target plants or new invasives. A successful restoration strategy at Boundary will likely require a combination of removing RCG and replanting with native trees, shrubs, and graminoids, especially given the re-establishment potential of RCG from seed, rhizome fragments, or nearby clones.

Kellogg C.H. and S.D. Bridgham. 2004. Disturbance, herbivory, and propagule dispersal control dominance of an invasive grass. Biological Invasions 6:319–329

Key Words: Disturbance, deer, glyphosate, propagule dispersal, herbicide, seed, biomass

This in-situ study examined the effects of non-catastrophic disturbance (glyphosate application) on plant communities initially consisting of monotypic stands of RCG in three northern Indiana hydrologically restored marshes (tile drains were removed). There were five treatments (control, enriched seed bank, disturbance, enriched seed bank + disturbance, and enriched seed bank + disturbance + deer exclosures) used to investigate the effects on biomass, richness, and diversity in the marshes. All treatments except deer-exclosed plots were $25m^2$. Average deer density in the study area was 38 deer km^{-2}. Greater propagule dispersal was simulated by seeding native marsh plants at a rate of 16.35 g m^{-2}. Short-term disturbance (herbicide application) was sufficient to assist native plant species to invade sample plots previously dominated by RCG. The combination of disturbance + enriched seed bank + deer exclusion was found to have the greatest impact on native species colonization of RCG monotypic stands. All of the treatments had limited effect on the dominance of RCG. The authors concluded that the presence and greater cover of native plants within exclosures was evidence that deer may selectively feed on and exclude native plants. Thus seeding and reduction of deer herbivory were found to assist native plant establishment and could be worth exploring in the pilot project at Boundary.

Kilbride, K. 2000. Integrated pest management to control reed canarygrass in seasonal wetlands of southwest Washington. In: Antieau, C.J. (ed). 2000. Final Proceedings of the Reed Canarygrass Working Group Conference, Olympia, WA.

Key Words: Disking, mowing, herbicide, Rodeo, hydrologic alteration, stem density, biomass

Several management practices, including disking or mowing, herbicide application (Rodeo) or combination of disking and herbicide in conjunction with water-level manipulation were used to control RCG in seasonal wetlands over a three-year study. Aboveground biomass of RCG was reduced most by a combination of repeated herbicide application and disking. Follow-up herbicide application (Rodeo) was required to effectively control regrowth of RCG from rhizomes that occurred following drawdown after the initial Rodeo application. The results of this study were published in the Wildlife Society Bulletin in 1999 (Wildlife Society Bulletin 27(2):292-297). The author was employed with the U.S. Fish and Wildlife Service in Vancouver, Washington. City Light has reached out to seek additional information on lessons learned.

Kim, K.D., K. Ewing, and D.E. Giblin. 2006. Controlling *Phalaris arundinacea* (reed canarygrass) with live willow stakes: a density-dependent response. Ecological Engineering 27(3):219-227

Key Words: Live stakes, willow, herbicide, mowing, mulching, density-dependent response, restoration

PNW study investigating use of live willow stakes to control RCG over two growing seasons. Examined the density-dependent response of RCG to three willow treatments 0.6 m (2 ft), 0.91 m (3 ft) and 1.21 m (4 ft) on center. Stakes were 3-ft long x 0.5 to 1-in. long. Half of the live stake was planted belowground immediately after harvest from the donor site. Site preparation included herbicide, mowing, and mulching (15-20 cm). Measured leaf area index of willow and aboveground biomass of RCG. RCG biomass was significantly reduced by 68% in the 2-ft spacing treatment and 56% in the 0.91-m spacing treatment, respectively compared to controls after two years. Control varied with willow density. Found significant positive relationships between soil moisture content and willow leaf area index (a surrogate for growth and biomass). Recommend denser (0.6-m and 0.91-m spacing on center) live stake planting for control.

Krueger, J.L., S.T. Bois, T.N. Kaye, D.M. Steeck, and T.H. Taylor. 2014. Practical guidelines for wetland prairie restoration in the Willamette Valley, Oregon: field tested methods and techniques. U.S. Environmental Protection Agency, Lane Council of Governments, Institute for Applied Ecology, and City of Eugene.

Key Words: Long-term management, wet prairie, succession, herbicide, mowing, flaming, burning, nutrient manipulation, grazing, seeding, restoration, thatch

This is an excellent guide on wet prairie restoration. The guide has six steps: 1) Site Selection; 2) Site Analysis; 3) Planning and Design; 4) Site Preparation; 5) Establishment; and 6) Long-term Management. Though this guide focuses on wetland prairie restoration, the long-term management section includes control of invasive species such as RCG. Chapter 6 on the Long-term Management Phase has a good discussion of the pros and cons of various control strategies, including burning, flaming, mowing or haying, grazing or browsing, herbicide, nutrient manipulation, and seeding. Burning, flaming, and haying are methods that can be used to reduce thatch, which is desirable to improve seeding success or germination of native plant seed in the soil seed bank. However, these methods are typically used in combination with other methods to be most effective. Goats readily eat RCG but any use of animals requires care to ensure that the animals do not introduce invasive plants through fecal matter or eat non-targeted plants. Burning in combination with herbicide application was the most effective treatment for controlling invasive grasses with minimal impacts on native prairie species. This treatment combination followed by seeding is recommended for prairie restoration, particularly if native plant diversity is low. Thatch from non-native grasses inhibits germination, establishment, and growth of native grasses and forbs. RCG produces a lot of thatch. If a goal of the wildlife enhancement is to improve plant species richness and diversity may be worth exploring if thatch removal is effective in promoting germination, establishment, and growth of native grasses and forbs at Boundary as part of the pilot project.

Lavergne, S. and J. Molofsky. 2006. Control strategies for the invasive reed canarygrass (*Phalaris arundinacea* L.) in North American wetlands: the need for an integrated management plan. Natural Areas Journal 26(2):208-214.

Key Words: Control, herbicide, restoration

Assessment of previous control strategies; potential new control strategies; research needed to improve control. Authors conclude that both physical and chemical controls in combination with hydrologic management are most successful. Most successful control strategies use a combination of management practices. Restoration of native plant community structure and composition is recommended to prevent regrowth or limit new infestations.

Lavergne, S. and J. Molofsky. 2007. Increased genetic variation and evolutionary potential drive the success of an invasive grass. PNAS 104(10):3883-3888

Key Words: Reed canarygrass hybrid, plasticity, tolerance

This is the best paper on the effects of uncontrolled, multiple introductions of European genotypes on North American populations of RCG since the mid-19th century. Introductions of European germplasm have resulted in novel RCG genotypes that have greater genetic diversity and phenotypic plasticity than the native species. Consequently, repeated introductions of European germplasm has created RCG genotypes with higher adaptive potential capable of exploiting and tolerating a wide range of conditions essentially creating hybrids with greater invasive potential. Resulting invasive genotypes have attributes such as faster emergence, higher tillering rates and leaf production than native genotypes indicating a higher potential for clonal spread and leaf canopy expansion.

Lindig-Cisneros, R. and J.B. Zedler. 2002. *Phalaris arundinacea* seedling establishment: effects of canopy complexity in fen, mesocosm, and restoration experiments. Canadian J. of Botany 80:617-624

Key Words: Shade tolerance, competition, canopy, woody species

This study reports on a series of experiments in a Midwest fen, fen restoration site, and fen-like mesocosms investigating the establishment of RCG from seed. Mesocosm experiment found that *Glyceria striata* planted with 1, 6, or 15 other native grasses and forbs all quickly formed a closed canopy preventing establishment of RCG from seed. RCG was only able to establish from seed after gaps were created in the canopy. When gaps are created in the canopy, species-rich canopies appear to be more resistant to invasion. Shade negatively affects RCG.

Lindig-Cisneros, R. and J.B. Zedler. 2001. Effect of light on seed germination in *Phalaris arundinacea* L. (reed canarygrass). Plant Ecology 155: 75-78.

Key Words: Germination rates, lab experiment, shade tolerance, disturbance

Paper reports the results of a lab experiment investigating RCG seed germination under different light conditions. Authors found that germination was photoperiod insensitive but germination rates were sensitive to different kinds of light (white, red, far red). Highest germination rates, up to 80 percent, were observed under white and red light. Lower rates, up to 40 percent were observed under far-red light. Virtually no germination occurs in the dark, supporting observations that canopy gaps are required for successful germination. The mechanism for seed germination is a phytochrome-mediated perception, which is consistent with observations that RCG seedlings readily establish after canopy disturbance.

This study in conjunction with the long-term wet prairie restoration success in the Willamette Valley of Oregon suggest that removing RCG and seeding a diverse mix of native graminoids and forbs may be a treatment worth exploring as part of a the pilot restoration project at BWP. The biggest challenge to this potential treatment may be finding sufficient local sources of seed and costs of collecting seed of native graminoid and forb species capable of competing with RCG.

Maurer, D.A. and J.B. Zedler. 2002. Differential invasion of a wetland grass explained by tests of nutrients and light availability on establishment and clonal growth. Oecologia 131(2):279-288

<u>Key words</u>: biology, nutrients, shade, field study, rhizome fragment, survival, growth flooding

Examined the emergence and survival response of RCG rhizome fragments using phytometers (growth chambers) in three different wetlands. To test the hypothesis that open canopies and increased nutrients facilitate vegetative establishment, the authors employed three levels of NPK fertilizer treatments and compared these to control plots. Found that emergence and survival varied significantly among wetland sites but not as a result of fertilization. Greenhouse experiments found that flooding and heavy shade significantly reduced aboveground biomass by up to 73% and 97%, respectively.

Maurer, D.A., Lindig-Cisneros, R., Werner, K.J., Kercher, S., Miller, R. and J.B. Zedler. 2003. The replacement of wetland vegetation by reed canarygrass (*Phalaris arundinacea*). Ecological Restoration 21(2): 116-119.

<u>Key Words</u>: Invasibility, germination, establishment, competition, stormwater, sediment, nutrients

This paper summarizes a number of different studies on factors limiting RCG that have been conducted primarily at the University of Wisconsin-Madison under the direction of Dr. Joy Zedler. For sedge meadow communities, it is concluded that sediment deposition and nutrient enrichment are the mechanisms for enabling RCG to become established and then dominant. Sediment deposition forms gaps in the sedge community canopy enabling RCG seedling establishment. Stormwater-borne nutrients then enable RCG to outcompete other species by allocating more growth to aboveground biomass and then ultimately enveloping and/or shading out smaller sedge-community competitors. The aggressive form of RCG in wetlands is believed to be the non-native Eurasian ecotype or a hybrid of the native and non-native ecotypes.

Merigliano, M. F. and P. Lesica. 1998. The native status of reed canarygrass (*Phalaris arundinacea* L.) in the inland Northwest, USA. Natural Areas Journal 18:223-230.

Key Words: Genotype, cultivar, invasive

Early specimens of RCG found throughout the Pacific Northwest between 1825 and 1911 were found along streams, lake margins, springs, and meadows. It was found to be most abundant in riverine habitats but rare or uncommon in meadows and springs. This historic distribution of the native type suggests that monocultures of RCG (i.e., aggressive North American genotypes) are hybrids of native populations and introduced European cultivars.

Miller, T.W., L. Potash Martin, and C.B. MacConnell. 2008. Managing reed canarygrass (*Phalaris arundinacea*) to aid in revegetation of riparian buffers. Weed Technology 22(3):507-513.

Key words: Riparian, willow, mowing, mulching, glyphosate, Pacific Northwest, tree protector, cost

Two-year Pacific Northwest study investigating riparian buffer restoration using four treatments: mowing (multiple), mulching (8 cm thick) plus trampling, spot herbicide application (1.5% glyphosate), or no management before transplanting arroyo willow and red alder. Treatments required varying levels of labor with spot spraying being the least labor intensive at the two study sites with near monocultures of RCG. Small plots were used, only 2.4 x 2.4 m (5.8 m^2). Both study sites (Lynden and Burlington) were treated with glyphosate in spring (April). 2.5-cm diameter rod used to make pilot holes ~46 cm deep for willow stakes. Bareroot alder planted in a shovel slit. Norplex tree protectors (60 cm tall, 13 cm diameter) were placed around half of the trees. There is brief mention of soil and diurnal temperatures at which translocation of herbicide to the roots and control are more effective. Tree protectors had a positive influence on willow growth at one of two sites. Willow cuttings were hardier and grew more quickly than red alder plantings. Lowest cost of all treatments for successful tree establishment was spot spraying with glyphosate. Authors concluded that annual spot spraying may be the most cost-effective means of achieving successful reestablishment of native broadleaf trees. Estimated costs for successful tree establishment ranged from $1.06 to $1.29 per tree for mid-summer spot spraying herbicide glyphosate each year to a high of $1.75 to $1.81 per tree for mulch the first year followed by trampling the second year (see Table 7).

Moore, S., D. Ward, and B. Aldrich. 2000. Transplanting large trees for reed canarygrass control. In: Antieau, C.J. (ed). 2000. Final Proceedings of the Reed Canarygrass Working Group Conference, Olympia, WA.

Key Words: Pacific Northwest, Snohomish County, shading, succession, salvage, planting, riparian

Snohomish County's Native Plant Salvage Program conducted an experiment during the winter of 1999-2000 salvaging and transplanting 40 native trees (2 to 8-inches diameter and 20 to 40-ft tall) in dense RCG. Once established, the trees were expected to provide shade and seed rain accelerating natural succession processes and controlling RCG. Sample plots were established exploring optimal spacing and planting densities needed to establish sufficient shade to control RCG. Monitoring was conducted. City

Light has reached out to Snohomish County's Scott Moore to obtain more details and identify lessons learned from this experiment.

Naglich, F. 2000. Using excavation and conifer establishment in managing reed canarygrass. In. Antieau, C.J. (ed). 2000. Final Proceedings of the Reed Canarygrass Working Group Conference, Olympia, WA.

Key Words: Pacific Northwest, Washington, excavation, control, black cottonwood, planting, conifers, Sitka spruce, western red cedar, Sitka willow, *Salix sitchensis*, red-osier dogwood, *Cornus sericea*, slough sedge, *Carex obnupta*

Ecological Land Services, an environmental consulting firm, used shading, excavation, and hydrologic alteration as part of a wetland mitigation project (enhancement) in Woodland, Washington. Black cottonwood (*Populus balsamifera*) trees were selectively removed and conifers were interplanted to increase shade to reduce the abundance and cover of RCG and Himalayan blackberry (*Rubus armeniacus*). In addition, some areas were excavated (and presumably the propagules of the invasive species removed) to alter hydrology and promote establishment of planted red-osier dogwood, Sitka willow, and slough sedge (*Carex obnupta*). Maintenance (removal of aboveground biomass of RCG and blackberry) was conducted for three growing seasons. Conifer plantings, willows, and slough sedge plantings reportedly have done well and appear to be self-sustaining. The author concludes that hand removal of invasive species is very labor intensive and difficult. City Light has reached out to Francis Naglich to obtain more details on the lessons learned some of which may be directly applicable to the Boundary Project.

Naglich, F.G. 1994. Reed canarygrass (*Phalaris arundinacea* L.) in the Pacific Northwest: growth parameters, economic uses, and control. Essay submitted in partial fulfillment of the requirements for the degree of Master of Environmental Studies, The Evergreen State College, Olympia, WA.

Key Words: Pacific Northwest, Nisqually Delta, mowing, control, spread, biomass

This paper is a field study of mowed and unmowed RCG at the Nisqually National Wildlife Refuge near Olympia, WA. The intent of the study was to examine the above and belowground biomass in mowed and unmowed area to assess whether mowing is an effective control method. It is suggested that regular mowing may be an effective means of reducing sexual and asexual reproduction and spread of clones.

Perkins, T.E. and M.V. Wilson. 2005. The impacts of *Phalaris arundinacea* (reed canarygrass) invasion on wetland plant richness in the Oregon Coast Range, USA depend on beavers. Biol. Conserv. 124:291–295.

Key Words: beaver, flooding, dam, species richness, beaver-impounded wetlands, Oregon, disturbance

(Reviewed only the abstract) Study in the Oregon Coast Range examining the relationship between RCG and plant species richness in beaver-impounded wetlands. Found that the disturbance of beaver dam formation created conditions favorable for reed canarygrass, which had negative effects on plant species richness.

Pfeifer-Meister, L. 2008. Community and ecosystem dynamics in remnant and restored prairies. PhD Dissertation, University of Oregon, Eugene, OR.

Key Words: Prairie, restoration, control, mechanism, ecosystem dynamics, Willamette Valley, succession, site preparation, nutrients, carbon, temperature, tilling, herbicide, solarization, diversity

Main objectives to develop an understanding of the mechanisms that influence upland and wetland prairie structure in the Willamette Valley, including soils, competitive controls over native and exotic species, and successional processes and applying understanding of these mechanisms to improving prairie restoration functioning. A combination of field and greenhouse experiments and analysis of site preparation techniques used at completed prairie restoration projects was used to better understand mechanisms driving plant community structure. Found that using a successional framework to guide restoration was important. Manipulation of moisture and temperature significantly influenced nutrient (nitrogen and phosphorus) and carbon cycling, which influenced competitive interactions between native and introduced grasses (tall fescue [*Schedonorus arundinaceus*] and annual ryegrass [*Lolium multiflorum*]) and thereby plant community structure. Introduction contains a nice description of integration of ecological theories (e.g., competition, invasion biology, abiotic factors, disturbance regime, and succession) into the practice of habitat restoration. Site preparation techniques had significant effects on plant communities (diversity, species richness, cover, and productivity but these dampened over time as the communities became more similar to one another. After 3 years, treatments remained significantly different than the controls. Studies showed the importance of timing of herbicide application on control of exotic species. Excavation of top 10 cm of topsoil to remove invasive species and weed seed significantly altered aboveground productivity, microbial biomass, mycorrhizal fungi, total soil carbon and nitrogen compared to reference prairies and solarization treatments even after 5 years.

Rice, J.S. and B.W. Pinkerton. 1993. Reed canarygrass survival under cyclic inundation. Journal of Soil and Water Conservation 48(2):132-135

Key Words: Flooding, reservoir, survival

The authors conducted a greenhouse experiment to determine the survival of RCG exposed to varying lengths of inundation on weekly cycles to determine the use of this species for shoreline protection in reservoirs. RCG survived inundation up to two days/week and in some situations up to three days/week. More recent regional publications reviewed herein contain better and more applicable information on the depth, duration, and frequency of flooding proven effective in controlling RCG.

Ruzicka, K.J., J.W. Groninger, and J.J. Zaczek. 2010. Deer browsing, forest edge effects, and vegetation dynamics following bottomland forest restoration. Restoration Ecology 18:702–710

Key Words: Deer, shading, control, forest restoration, diversity, exclosure, afforestation, competition

Authors report on an investigation of tree species composition in bottomland hardwood forest in Illinois five and seven years after forest restoration. Deer browsing was found to influence forest stand composition, density, and stem height as a function of distance from the nearest forest edge on a 526-hectare site in southern Illinois. It is concluded that deer browsing has the potential to delay or prevent crown closure in areas where the density of non-preferred tree species is low. Given the potential for preferential deer browsing to influence canopy closure and invasion by herbaceous species, the authors suggest that deer management may be beneficial at both the time of establishment and early stand development. Herbivory by deer, beaver, and voles is known significantly affected growth, survival, and success of wetland restoration projects in the state. Thus for the Boundary pilot project, it may be advisable to include deer/beaver exclosures as a treatment to assess the potential influence of herbivory on woody species establishment and control of RCG.

Schat, M., McEvoy, Coombs, E. 2000. Integrated control of reed canarygrass and purple loosestrife. In: Antieau (ed). 2000. Final Proceedings of the Reed Canarygrass Working Group Conference, Olympia, WA.

Key Words: Mowing, tilling, herbicide, burning, flooding, Baskett Slough National Wildlife Refuge, Oregon, diversity

Five management strategies (mowing, tilling, herbicide, burning, and flooding) were evaluated in efforts to control RCG and purple loosestrife at Baskett Slough National Wildlife Refuge in Polk County, Oregon. Flooding, tilling, and herbicide were found to be best for reducing RCG abundance and increasing native plant diversity and abundance.

Seebacher, L.A. 2008. *Phalaris arundinacea* control and riparian restoration within agricultural watercourses in King County, Washington. Ph.D. dissertation, University of Washington, Seattle, WA.

Key Words: live stakes, compost, hogfuel, biomass, dissertation, Washington, University of Washington

Three barrier treatments + native canopy to reduce RCG vigor over 2 years:

- Burlap, ~25 cm (~10 in.) compost, plus a second layer of burlap – RCG Barrier treatment least effective;
- Burlap, 25 cm Hogfuel, burlap, second layer of burlap, and 3-ft (90 cm) willow (*Salix sitchensis*) stakes (12 stakes/plot or 0.5 m (1.6 ft o.c.) - reduced RCG biomass by 64%;
- 25 cm Hogfuel, burlap, 25 cm compost, 2nd layer of burlap, and multi-canopy (*Scirpus microcarpus*, *Rubus spectabilis, Lonicera involucrata, Symphoricarpos albus, Rubus parviflorus, Cornus sericea, Salix sitchensis, Ribes bracteosum*) - reduced RCG biomass by 56%.

Three replicates of each treatment and control were used at each of the three different sites (natural and two agricultural sites) in a randomized block design. Plot size varied from 2 x 3 m at the natural and one agricultural site to 1 x 2 m at the other agricultural site. All three treatments significantly reduced RCG compared to controls. Western red cedar use for hogfuel was recommended because of its favorable weight, nitrogen reduction, and allelopathic characteristics, which may help suppress RCG regrowth and seed germination. Willows were attacked and up to 80% destroyed by the poplar and willow borer (*Cryptorhynchus lapathi*) reportedly ubiquitous in western Washington. Damaged willows were cut off, removed from the site and destroyed in an effort to prevent additional larvae from maturing. Many of the willows recovered, however, shade for controlling RCG was greatly reduced in the short term.

It is uncertain if this introduced weevil exhibits classical population cycles in response to predators, but similar damage has been observed at other sites in western Washington, resulting in short-term changes in willow canopy cover. However, without any attempts to control the pest, willows recovered by crown sprouting (personal observations, S. Luchessa) and continued to suppress RCG regrowth and density. Nonetheless, a multi-species canopy with other species that are known to reproduce well from live stakes that are not susceptible to this pest may be advisable at the BWP. This would result in canopy cover that would not be as vulnerable to infestations and potentially set back RCG control efforts. Potential candidate species could include red-osier dogwood, various *Ribes* species, black twinflower (*Lonicera involucrata*), and other species that have been shown to successfully reproduce from hardwood cuttings in Washington.

<u>22 week, Interspecific greenhouse competition experiment with *Scirpus microcarpus* (SFB)</u>:

- High (1 in. standing water maintained in tray) vs. low soil moisture (800 mL water/wk), and
- High (66.08 ppm N) vs. low (9.46 ppm based on natural N levels at Duvall site) nitrogen addition.

Control (RCG/RCG) and treatment (one plant ea. of RCG/SFB). Although the competition experiment did not result in statistically significant reduction of RCG biomass in any treatment, a trend in reduced RCG biomass was noted in the high soil moisture + high nitrogen treatment.

<u>Carbohydrate reserve and barrier (opaque material)</u>:

Rhizomes removed from the parent clone and placed under an opaque material were tested for fructosans after 3, 6, and 9 months. Though there was no significant fit for the regression, average fructosan content (reserves) in rhizomes after 6 and 9 months was considerably reduced indicating a weakened ability to survive. This suggests that tilling followed by mulching, may be an effective control strategy.

<u>RCG and Invasive species biology</u> – There is a good discussion of these. RCG is well adapted to invading wetlands and riparian areas, which tend to be regularly disturbed by flood events and influxes of debris. A C3 species. Reproduces both sexually and asexually. High seed viability (95%)

<u>RCG control literature review</u> – Good summary of control strategies: chemical, mowing and grazing, excavation of substrate, water level manipulation, micronutrient (boron) and macronutrient (N) management, burning, shading. No universal strategy for effective removal and re-establishment of native vegetation. Optimum C:N reportedly is on the order of 10:1 for C addition (e.g., wood chips).

Stannard, M. and W. Crowder. 2001. Biology, history, and suppression of reed canarygrass (*Phalaris arundinacea* L.). Technical Note 43. Plant Materials Center, Natural Resources Conservation Service, U.S. Department of Agriculture, Spokane, WA.

Key Words: Biology, history, management practices, till, flooding, chemical (herbicide), mowing, grazing, excavating, burning, cultivar, aboveground biomass,

Good description of vegetative (clonal) growth, seed production, and biomass production. Excellent description of introduction history and cultivars. European seed companies exported seed to North America until about 1924. First documented seed production in the western U.S. is reportedly 1885 in the Coquille Valley of Oregon, which was probably a local variety. The first registered variety of RCG "Ioreed" was released in 1946 by the Iowa Agricultural Experiment Station. Use of RCG in the PNW began at the turn of the century (late 1800s). Report aboveground biomass production (hay) as high as 9 tons/acre. Invasive characteristics make natural transition to higher seral "more native" state unlikely. Discussion on control methods (tillage, flooding, herbicide, mowing/grazing, shading, burning, competition, scalping, biocontrol) includes short descriptions of the advantages and disadvantages of each. Combination of methods is most effective.

Stevens, M. and R. Vanbianchi. 1993. Restoring Wetlands in Washington: A Guidebook for Wetland Restoration Planning and Implementation. Washington State Department of Ecology Publication 93-17, Olympia.

Key Words: Guide, wetland restoration, site assessment, planning, implementation

This is an older guidebook that contains information that has been in large part superseded by more recent interagency guidance on wetland mitigation and restoration. More recent interagency guidance contains better and more detailed information on restoration site assessment, planning, implementation, and monitoring. The section on controlling aggressive plants at the end of the document is still applicable. Cut and cover, burning, flooding, shading with plantings of woody species, and control with herbicide are all discussed. It is suggested that flooding areas with ≥ 5 ft of water for at least three growing seasons has successfully eliminated RCG. More recent publications suggest effective control can be achieved by flooding RCG for shorter periods or time in combination with reintroduction of woody native plants. Flooding to such depths for such long duration is likely not practicable at Boundary. However, flooding in conjunction with other control methods (e.g., planting live stakes) may be effective.

Thomsen, M., K. Brownell, G. Matthew, and E. Kirsch. 2012. Control of reed canarygrass promotes wetland herb and tree seedling establishment in an upper Mississippi River floodplain forest. Wetlands 32:543–555

Key Words: Deer, pre-emergent herbicide, exclosure, tree seedling, growth, competition

Field and lab studies in the upper Mississippi watershed investigating the competitive effects of RCG on native floodplain forest plant diversity and native herb and tree seedling establishment. Good discussion of factors contributing to the competitive ability of RCG, including high propagule production and broad environmental tolerance. "Recent genetic analyses have led to the conclusion that invasive strains resulted from the introduction of multiple European genotypes (Lavergne and Molofsky 2007)." Three-year field study found combination of late fall scarification and pre-emergent herbicide application (Oust XP and Pendulum) positively influenced native herb and tree seedling germination. Cuttings of black cottonwood, black willow, sandbar willow, and red-osier dogwood were planted in treated areas but had low survival possibly from pre-emergent herbicide treatment. Data from small exclosures demonstrated that deer browsing can limit tree seedling growth and will delay canopy closure possibly facilitating RCG re-invasion. Trees seedlings in exclosures were >50% taller than browsed counterparts. Suggest exclosures may be more cost effective to reduce time to canopy closure than repeat herbicide treatments to control re-invasion and competition from RCG. These results suggest that tree protectors or exclosures are advisable for future mitigation projects at Boundary to reduce maintenance costs and improve the effectiveness of habitat mitigation (e.g., improving browsing) "Observations to date suggest that where canopy gaps have been invaded by reed canarygrass, management action is necessary to restore the site to forest." "Angiosperm trees can be kept in a perpetual sapling condition by ungulate browsers, as the removal of apical buds promotes lateral branching, resulting in an increasingly shrubby growth form (Hobbs 1996)" as cited in this paper. These statements and the author's personal experience with heavy deer and beaver browsing demonstrate that desired outcomes can be prevented without intervention. City Light is considering including an exclosure treatment as part of the pilot restoration project at BWP.

Tu, M. 2004. Reed canarygrass (*Phalaris arundinacea* L.) control & management in the Pacific Northwest.

Biology (general), restoration steps, good discussion on control strategies and their effectiveness (see also Bugwood Wiki website for most recent information). For large monocultures, three recommended strategies: 1) Mow/herbicide; 2) Burn/herbicide; 3) tillage/flooding

Washington State Department of Agriculture and Washington State Department of Ecology. 2004. Integrated pest management plan for freshwater emergent noxious and quarantine listed weeds. WSDA and Ecology, Olympia, WA.

Key Words: Integrated pest management, IPM, impacts, management practices, control methods

This document provides a good overview of the state process for designating noxious weeds and the different classes of noxious weeds (Class A, Class B, and Class C) and the legal requirement for landowners to control them. It also contains a nice review of the impacts of noxious weeds, including economic costs, water quality and habitat degradation, and reduced biodiversity. The integrated pest management (IPM) process for controlling or eradicating noxious weeds and the legal authorities requiring state agency use of IPM are presented. There are detailed profiles of a number of the worst freshwater emergent noxious weeds, including RCG, in Appendix A. Profiles contain species-specific information on distribution and impacts and control methods. Much but not all of the information in the profile on RCG is contained in more recent documents reviewed in this annotated bibliography.

Wetzel, P.R. and A.G. van der Valk. 1998. Effects of nutrient and soil moisture on competition between *Carex stricta, Phalaris arundinacea, and Typha latifolia.* Plant Ecology 138:179-190

Key Words: Biomass, competition, resource allocation, nutrients, light

This short-term competition experiment investigated the effects of nutrients, soil moisture, arbuscular mycorrhizal fungi (AMF), and competition on three perennial wetland plant species grown in the laboratory from seed. Nutrients had the greatest impact on biomass for all three species compared to other variables (soil moisture, AMF, and competition). Competition with RCG reduced the biomass of both *C. stricta* and *T. latifolia*. Authors attributed this to the rapid growth rate and architecture (horizontal leaf orientation vs. vertical) of RCG. RCG effectively outcompeted the other two species for light.

Wisconsin Reed Canarygrass Working Group. 2009. Reed canarygrass (*Phalaris arundinacea*) management guide: recommendations for landowners and restoration professionals. PUB-FR-428, Wisconsin Department of Natural Resources, Madison, WI

Key Words: Working Group, Wisconsin, management guide, custom seed mix, management considerations, management practices, herbicide, mowing, haying, burning, flooding, excavating, planting, grazing, tilling, mulching, modifying hydrology, site assessment, seeding rate

Good introduction on the life cycle of RCG and traits that give this species a competitive advantage over many native plants. Nice pictures of RCG life history phases that could be useful in the design and development of the pilot habitat enhancement project at Boundary. Like many references, these authors conclude that effective treatment of monocultures will require several years (minimum of 3 to 5) using a combination of management practices and an adaptive management approach. The publication contains nice tabular summaries for assessing what management practices or control strategies to use, the various pros and cons of these techniques, and guidelines for developing a custom seed mix. Though much of the guidance is focused on wet meadow restoration using various management practices in combination with seeding in the Midwest, these practices are broadly applicable. Site assessment to help determine the cause of the RCG invasion is an important step to successfully control. When feasible the underlying causes should be addressed. In the case of Boundary, hydrological modification and nutrient enrichment from upstream, non-point sources are likely to be contributors and may be impossible to address. Like others, these authors conclude that creating a closed canopy as quickly as possible is critical to preventing re-establishment of RCG.

Zedler, J.B. and S. Kercher. 2004. Causes and consequences of invasive plants in wetlands: opportunities, opportunists, and outcomes. Critical Reviews in Plant Sciences 23(5):431-452

Key Words: Invasive, disturbance, tolerance, competition, water quality, nutrients.

This review contains a good discussion of the attributes of invasive wetland plants, including RCG. The authors also provide a review of five causes and consequences of invasions based upon available data: enemy release, broader tolerance, efficient use, hybrid vigor, and allelopathy. Part of the success of RCG is the plants ability to start growing earlier and later (i.e., extended growing season) enabling it to outcompete smaller stature native plants. The authors suggest that wetlands with enhanced runoff, sediments, and nutrients are vulnerable to invasion by RCG. It is clear that at least some areas at the

Boundary Hydroelectric Project (e.g., Boundary Wildlife Preserve) appear to fit this paradigm. The hydrology of the Pend Oreille River has been altered by dam construction and nutrients are likely elevated by nonpoint sources of pollution, especially agriculture.

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